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(54) **Electro magnetic display pixel driving system**

(57) New technical solution of the electromagnetic display pixel driving system solves the problem of switching the display pixel flap between two bistable »ON« and »OFF« positions. The magnetic circuit of the display pixel consists of a permanent magnet (2c) in the display pixel flap (2) and an electro-magnet (5+3u) with a magnetic core (3u). Said permanent magnet (2c) is made using an injection molding process and

is divided in two areas with antiparallel direction of magnetization, which is also perpendicular to the flap's surface (2a, 2b) and pivoting axis (2d). Electro magnet (5+3u) is placed under the flap (2) and has a preferably U shaped magnetic core (3u), which is oriented parallel to the pivoting axis (2d). This design minimizes the stray magnetic field and interactions between neighboring display pixels.

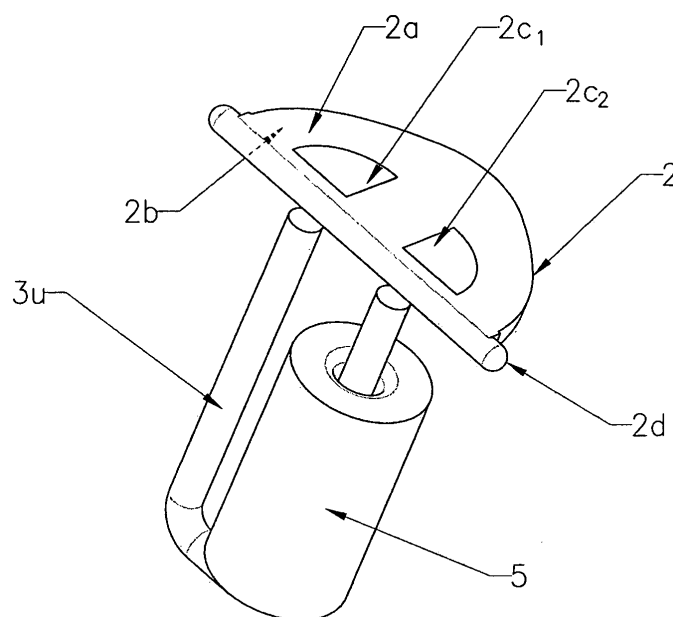


Fig. 1.

Description

OBJECTIVE OF THE INVENTION

[0001] Objective of the invention is a construction, materials and process of manufacturing of the magnetic circuit of the display pixel in electromagnetic display panel, which actuates the rotation of the display pixel flap.

TECHNICAL FIELD OF THE INVENTION

[0002] Present invention is classified in the group of bistable magnetic actuators, which are based on interaction of the magnetic field of a permanent magnet built in display pixel flap and the magnetic field of the core of an electromagnet.

[0003] According to international patent classification, the patent application is classified in groups H01F 3/14, H01F 7/14 and H01F 7/121, its use is classified in groups G09F 3/4 and G09F 9/37.

TECHNICAL PROBLEM

[0004] The technical problem solved by the present invention is to provide a novel, simple, compact and low production cost construction, of a display pixel electro magnetic driving system.

[0005] This electro magnetic system is actually a bistable actuator, which has to switch the display pixel from a first bistable position into a second bistable position (and reverse) with minimum power consumption. Therefore the magnetic circuit must be specially designed including materials with special magnetic properties. Besides this the design of the magnetic circuit has to be optimized to allow for the reduction of the magnetic interaction between neighbouring display pixels as much as possible. The system must work in wide temperature range and has to guarantee the stability of both bistable positions of the display pixel flap. If the external forces resulting from mechanical stress, shock, vibrations or similar would result in changing the position of the display pixel flap, the remanent magnetic forces on the display pixel flap should be sufficient to restore the required position immediately after the external forces disappear.

BACKGROUND OF THE INVENTION

[0006] The electromagnetic display panels have been known for over two decades and are playing an important role in niche applications, where relatively large size, medium information content display panels, with high contrast and excellent visibility in rather high ambient lighting conditions are required. The bistable electromagnetic display panels (US 3,871,945, US 4,577,427, US 4,860,470, EP 0 084 959, EP 0 731 435 A1, US 4,243,978, US 5,771,616, US 6,272,778, US 6,025,825, US 5,898,418, US 6,603,458,...), used for

traffic signs, buses' and trains' destination displays, large information display panels in airports, bus and railway stations and sporting events seem to comply very well with the above requirements. Using bright reflective paints on the selected picture elements and mate black on the nonselected areas, these displays feature good contrast and excellent angular visibility in high ambient light conditions.

[0007] The operating principle of the present state-of-the-art solutions is predominantly based on the movable pixel flap rotating around the pivoting axis for typically $\leq 180^\circ$ just inward the mechanical limiting positions and having the size of the entire display pixel. The flap is painted on its front and rear side with visually highly contrasting colors (EP 0327250, US 6,272,778, US 6,025,825, US 5,898,418,...). In order to switch between the "on" and "off" state of the display pixel, these solutions typically use one fixed permanent magnet inserted in the movable pixel flap and a built-in solenoid wound around either straight (EP 0327250, US 6,603,458, US 6,272,778,...) or U-shaped magnetic core (US 4,243,978, US 6,025,825, US 5,898,418, US 5,005,305,...). Some technical solutions use an additional fixed permanent magnet to improve the stability of the bistable positions of the flaps (US 4,243,978, US 4,531,318).

[0008] There is yet another, substantially different operation principle known, based on display pixels, which are divided into two parts. Each pixel is provided with a rotatably mounted, bistable tilting flap, which is asymmetrical in relation to its rotational axis. The tilting flap covers one of the two portions of the panel surface in the pixel zone, when the flap lies in each of its two stable positions. The side of the tilting flap facing the front side of the panel and the portion of the panel in the pixel zone covered by it are painted in one and the opposite side of the flag and the remaining part of the pixel zone are printed with different, highly contrasting color to the first one (US 6,603,458, DE 3501912C2, DE 3601018A1). In order to switch between the "on" and "off" state of the display pixel these solution uses a permanent magnet inserted in each tilting flap in close proximity to the rotational axis. The tilting flap is rotated from a first bistable position into a second bistable position by an electromagnet with a straight magnetic core, which is located on the reverse side of each display pixel. Such a construction has a certain advantage over the other state of the art solutions, as the entire construction can be noticeable thinner (only one half of the pixel surface rotates around the pivoting axis!) than with the technical solutions as described before.

SUMMARY OF THE INVENTION

[0009] The object of this invention is to increase the efficiency and reliability of a display pixel magnetic driving system, which moves the display pixel flap between »ON« and »OFF« state of the pixel. The pro-

posed solution minimizes power consumption, increases the stability of the flap in both bistable positions, minimizes the interaction between the neighbouring display pixels and allows for more compact pixel design with smaller number of constituent parts and automatized pixel production as well as thinner display pixel.

[0010] Present invention provides a new design of the magnetic circuit, which creates the magnetic torque acting on the display pixel flap in two separate areas according to claim 1. With two acting areas the magnetic torque on display pixel is increased.

[0011] This is preferably achieved by a U shaped solenoid core and (one or two) permanent magnets on the flap. The U-shaped core 3u (Fig. 1) is located under the display pixel flap pivoting axis 2d as close as possible to the flap and parallel to the display pixel flap pivoting axis 2d, unlike the state-of-the-art solutions using an U shaped magnetic core. Such a position and orientation of the U shaped coil core significantly reduces the dependence of flap position on magnetic torque compared to the above mentioned state-of-the-art solutions and reduces the display thickness. The permanent magnet arrangement in the flap is either in one piece with antiparallel direction of magnetization, which is also perpendicular to the flap surface and perpendicular to pivoting axis, or divided in two separate segments, which are also magnetized antiparallel. The magnets are preferably made of plastic bonded NdFeB material or plastic bonded ferrite material in an injection molding process.

[0012] The design of the magnetic circuit can be optimized by the proper choice of materials using the finite elements method to minimize the energy consumption required for switching from one stable position of the display pixel flap to another. The efficiency of the magnetic system, reliability and stability of both bistable positions of the display pixel flap are provided by the increased magnetic torque. The proposed design of the magnetic circuit minimizes the stray magnetic field and reduces the magnetic interaction between neighbouring pixels. Therefore there is no need for antiparallel orientation of the magnets in neighbouring display pixel flaps as is the case in US 6,606,458 patent.

DESCRIPTION OF DRAWINGS

[0013] This invention may be better understood and its objectives and advantages will become apparent to those skilled in the art by reference to the annexed drawings as follows:

Fig. 1. -Magnetic switching system using a U-shaped electromagnet (3u+5) including:

- Rotatable flap 2 with built-in (plastic bonded NdFeB or plastic bonded ferrite) magnets 2c₁, 2c₂ and a pivoting axis 2d; The two surfaces of the flap 2a and 2b are painted with highly contrasting colors,

- Solenoid 5
- U-shaped magnetic core 3u

Fig. 2. - Construction of segment of the display with electromagnetic switchable display pixels.

Fig. 3. Stray magnetic field

•Fig. 3a - Magnetic field computer modeling in stable flap position for U shape magnetic core.

•Fig. 3b - Magnetic field computer modeling in unstable flap position for U shape magnetic core.

•Fig. 3c - Magnetic field computer modeling in stable flap position for straight magnetic core.

•Fig. 3d - Magnetic field computer modeling in unstable flap position for straight magnetic core.

Fig. 4. - Display pixel flap production concept.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Electromagnetic display pixel driving system according to the invention is described in detail using Figures 1 - 4:

In the magnetic system for switching the display pixel between »ON« and »OFF« state according to the invention the electromagnet has the preferably U shaped magnetic core oriented along the flap's pivoting axis while the orientation of the magnets in all flaps of the display is the same.

[0015] The display pixel flap has a built in permanent magnet arrangement, which is divided into two areas 2c₁ and 2c₂. The directions of magnetization of these two areas are antiparallel to each other and perpendicular to the pivoting axis of the flap 2d as well as to the flap surface. The magnet in the flap 2 can be optionally divided in two separated segments 2c₁ and 2c₂ as shown in Fig. 1. In this figure the magnetic system consists of the flap 2 with two permanent magnets and an electromagnet (3u+5). The relative magnetization directions of those two magnet segments are the same as in case of one magnet with two areas. The magnets are made of plastic bonded NdFeB material or plastic bonded ferrite material. The production of the display pixel flap is made in two component injection molding process, during which the magnets are molded during the first step and the rest of the flap is filled with plastic in the second. The magnets are molded in the presence of magnetic field, which creates anisotropic magnetic properties, increases the magnetic flux density and gives consequently higher magnetic torque. Such a process results in sufficient magnetic torque for the dis-

play pixel flap. In spite of using plastic bonded hard magnetic materials, the magnetic properties of which are noticeably inferior to the sintered materials, the above described process still results in sufficient magnetization of the permanent magnets built-in the display pixel flap. The magnetization of plastic bonded ferrite magnets is preferably made by permanent rare earth magnets built-in the molding tool. In case of use of plastic bonded Nd-FeB magnets, the magnetization is preferably made by specially designed current loop built-in the molding tool, which is powered by a very short pulse of a very high electric current. The magnetization of the built-in plastic bonded ferrite magnets is made simultaneously for all (for example 14) flaps in a set (Fig. 4). All the flaps in the display have the same magnetic orientation, unlike the solution with straight magnetic core as described in US 6,603,458. This significantly simplifies the production and makes process automation easier.

[0016] The electromagnet consists of a solenoid (coil) 5 and the U shaped coil core 3u. It is placed under the rotation axis of the flap and is parallel to the axis (Fig. 1 and Fig. 2). Such an orientation reduces the influence of the flap position on the magnetic torque compared to the state-of-the-art solutions, where U shaped core is oriented perpendicular to the rotation axis.

[0017] The solenoid (coil) is wound up on a plastic solenoid body 1e (Fig. 2), which is part of the monolithic block 1 forming several display pixels. The ends of the solenoid wires are soldered to mounting pins 4a and 4b, which are inserted in receptacles 1c and 1d.

[0018] Magnetic core 3u has a U shape and is made of a cylindrically shaped semi hard magnetic material, which gets its final magnetic properties only after adequate thermal treatment. One leg of the core is inserted in the coil 5, the other leg is inserted in block 1 to fix its position. The U shaped core enables building thinner displays compared to the case with the straight coil core.

[0019] The magnetic circuit of the display pixel (consisting of the magnetic core of the electromagnet, the magnets in the flap and the air gap between the magnetic core and magnets) is designed and optimized using 3D computer modeling software and is optimized according to the magnetic properties of the materials used. The magnetic field in the stable as well as unstable flap positions is shown on Fig. 3.

[0020] This invention is characterized by two simultaneously acting areas of magnetic force in the display pixel flap, which create magnetic torque. Such a construction increases the magnetic torque, which is also enhanced by increased magnetic field density when using the electromagnet with the U shaped magnetic core. In comparison to the straight magnetic core, the U shaped magnetic core has significantly less stray magnetic field (Fig. 3). Higher magnetic torque increases the stability of the display pixel flap in "ON" and "OFF" positions.

[0021] Less stray magnetic field reduces the crosstalk between neighbouring pixels and consequently all the flaps in the display have the same magnetic orientation.

Switching from one flap position to another is made by a current pulse through the solenoid 5, which reverses the magnetic field in the magnetic core. Changing the direction of the magnetic field in the magnetic core of the electromagnet makes the current position of the flap unstable and turns the flap in second stable position, which remains stable after the current pulse is terminated.

10 EXAMPLE

[0022] An electromagnetic display panel is typically composed of a number of substantially square display pixels organized in display matrix. Due to a reasonably large number of display pixels, the standard production concepts, based on assembling the constituent parts of individual display pixels directly on the display panel main PC board, turns out to be a complex and expensive operation. To reduce costs and simplify the production, 7 pixels are joined in one monolithic block, which is a basic element for building the display matrix. The monolithic block 1 (Fig. 2) is made of black mate plastic in an injection molding process. After the molding, the block is painted with contrast color in the 1a areas. Then the mounting pins 4a and 4b are inserted in receptacles 1c and 1d. Next operation is winding 7 solenoids on monolithic block 1 and soldering the ends of the winding on mounting pins and testing the ohmic resistance of the windings.

[0023] Magnetic core 3u has a U shape and is made of cylindrically shaped rod of semi hard magnetic material, which gets its final magnetic properties only after adequate thermal treatment. One leg of the core is inserted in the coil 5, the other leg is inserted in block 1 to fix its position. The ends of both legs of the core are located under the rotation axis of the flap 2 and are oriented parallelly to the said axis.

[0024] The rotatable flaps 2 are manufactured separately. As the flaps 2 have to have built-in permanent magnets 2c₁, 2c₂ the latter are made using plastic bonded ferrite materials in a two-component injection molding process. Just like with the monolithic block 1 one side 2a of the flaps is painted with the same bright fluorescent paint, while the other half 2b is kept unpainted - mate black original plastic surface.

[0025] The display pixel flap has a built in permanent magnet arrangement, which is divided in two areas (segments) 2c₁ and 2c₂. The direction of magnetization of those areas are antiparallel to each other and perpendicular to the pivoting axis of the flap 2d as well as to the flap surface. Magnets are made of plastic bonded NdFeB material or plastic bonded ferrite material. The production of the display pixel flap is made in a two component injection molding process, during which the magnets are molded during the first step and the rest of the flap is filled with plastic in the second. Magnets are molded in the presence of magnetic field, which creates anisotropic magnetic properties, increases the magnet-

ic flux density and gives consequently higher magnetic torque. Such a process results in sufficient magnetic torque for the display pixel flap. In spite of using plastic bonded hard magnetic materials, the magnetic properties of which are noticeably inferior to the sintered materials, the above described process still results in sufficient magnetization of the permanent magnets built-in display pixel flap. The magnetization of the plastic bonded ferrite magnets is made by permanent rare earth magnets built-in the molding tool. In case of use of plastic bonded NdFeB magnets, the magnetization is made by specially designed current loop built-in the molding tool, which is powered by a very short pulse of a very high electric current. The magnetization of the built-in plastic bonded ferrite magnets is made simultaneously for all 14 flaps in the set (Fig. 4). All the flaps in the display have the same magnetic orientation, unlike the solution with straight magnetic core in US 6,603,458. This significantly simplifies the production and makes process automation easier.

[0026] In order to achieve the most economic production, 14 flaps are injection-molded at the same time in two rows of seven flaps (see Fig. 4), connected together with spacers **19**, which keep them positioned at exactly the same place/distance, as determined by the 14 pivoting axes' bearings **1f**, **1g** on the monolithic block **1** in order to optimize final display segment (7 pixels) assembling process. Just like with the monolithic block **1** one side **2a** of the flaps is painted with the same bright fluorescent paint, while the other half **2b** is kept unpainted - mate black original plastic surface. After the flaps **2** are painted, the spacers **19** are simultaneously cut away and the two rows of 7 flaps **2** are simultaneously "snapped-in" the 14 pivoting axes' bearings **1f**, **1g** on the monolithic block **1**.

Claims

1. Magnetic system for switching an electromagnetic display pixel flap of a display pixel consisting of a rotating flap (2) having two bistable positions and an electromagnet (5+3u) with a magnetic core (3u) and a solenoid (5), which moves the flap (2) from one bistable position into another by a current pulse, wherein the rotating flap (2) has a built-in magnet arrangement (2c) and the electromagnet (5+3u) is located under the flap (2), **characterized in that** the magnetic core (3u) is shaped in such a way that a magnetic force and hence a magnetic torque is generated simultaneously in two spatially separate areas of the flap (2).
2. Magnetic system for switching the electromagnetic display pixel flap according to claim 1, **characterized in that** the magnet arrangement (2c) in the rotating flap is divided into two areas or formed of two separated segments (2c₁ and 2c₂), and that these areas or segments are magnetized antiparallel and perpendicular to a flap surface (2a, 2b) and perpendicular to a flap pivoting axis (2d).
3. Magnetic system for switching the electromagnetic display pixel flap according to claim 2, **characterized in that** the magnet arrangement (2c) is placed close to the pivoting axis (2d) and that the two separated segments (2c₁ and 2c₂) are shaped rectangular or as ¼ of a cylinder.
4. Magnetic system for switching the electromagnetic display pixel flap according to any of claims 1 to 3, **characterized in that** the magnetic core (3u) is U shaped and is oriented parallel to the pivoting axis (2d).
5. Electromagnetic display panel with a plurality of display pixels having the magnetic system according to any of claims 1 to 4, **characterized in that** all magnet arrangements (2c) built-in the flaps of the display panel have the same antiparallel magnetic polarisation.
6. Process of manufacturing of the magnetic system for switching the electromagnetic display pixel flap according to claims 1 to 5, **characterized in that** the flap (2) built-in magnet arrangement (2c) is made in an injection molding process of plastic bonded hard magnetic material and that the molding process is made in the presence of a strong magnetic field, which gives anisotropic properties to the plastic bonded magnets (2c).
7. Process of manufacturing of the magnetic system for switching the electromagnetic display pixel flap according to claim 6, **characterized in that** the magnet arrangement (2c) is made of plastic bonded ferrite material and is magnetized by properly shaped permanent magnets made of rare earth, which are built in the molding tool.
8. Process of manufacturing of the magnetic system for switching the electromagnetic display pixel flap according to claim 6, **characterized in that** the magnet arrangement (2c) is made of plastic bonded NdFeB material and is magnetized by a special current loop, which is built-in in the molding tool, and **that** a current pulse is applied during the molding process, while the magnet bonding plastics is still soft.
9. Process of manufacturing of the magnetic system for switching the electromagnetic display pixel flap according to one of claims 1 to 8, **characterized in that** the solenoid (5) is wound up directly on a plas-

tic monolithic block (1) and that the ends of solenoid wire are connected to mounting pins (4a, 4b), which are inserted in receptacles (1c, 1d) in said monolithic block (1).

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10. Process of manufacturing of the magnetic system for switching the electromagnetic display pixel flap according to one of claims 1 to 9, **characterized in that** a stray magnetic field as well as an interaction between neighboring pixels are minimized.

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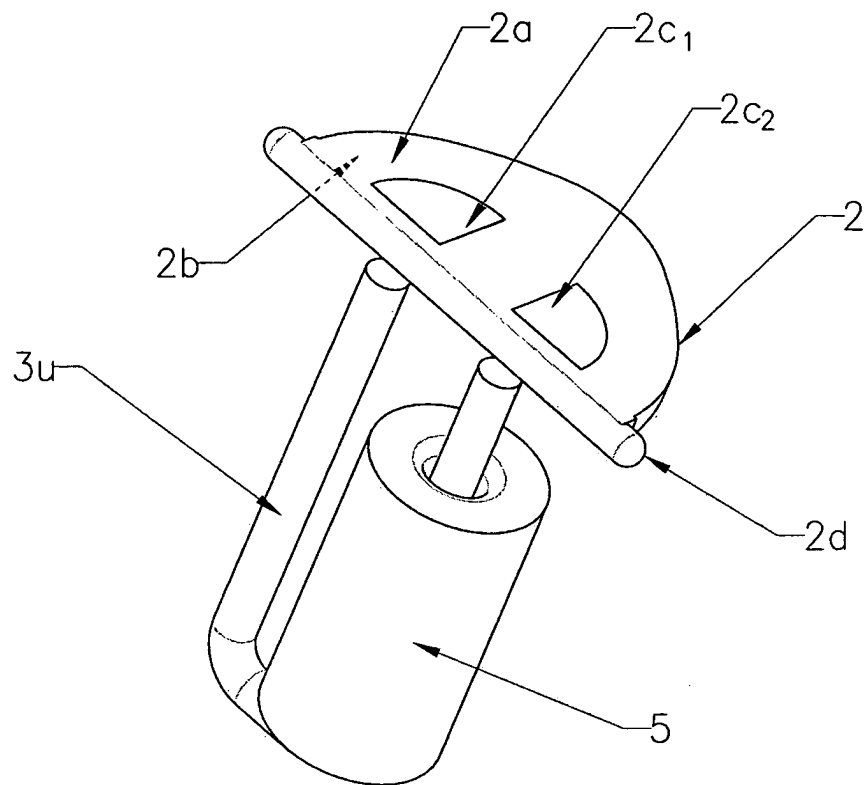


Fig. 1.

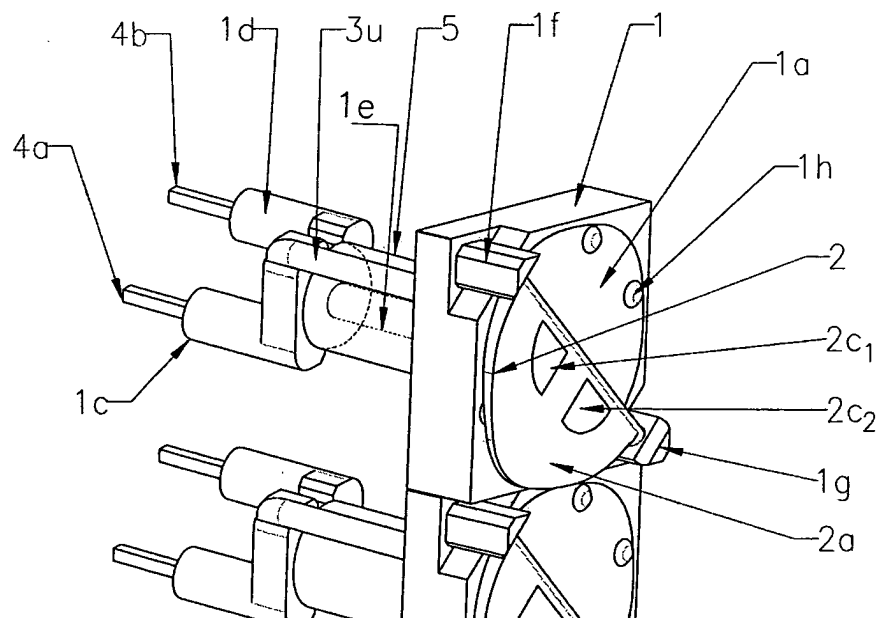


Fig. 2.

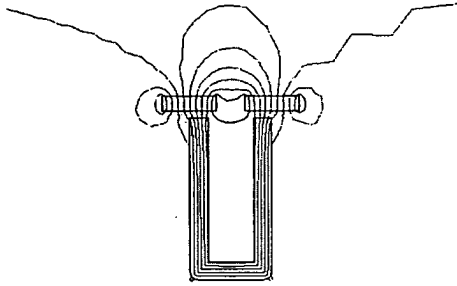


Fig. 3.a

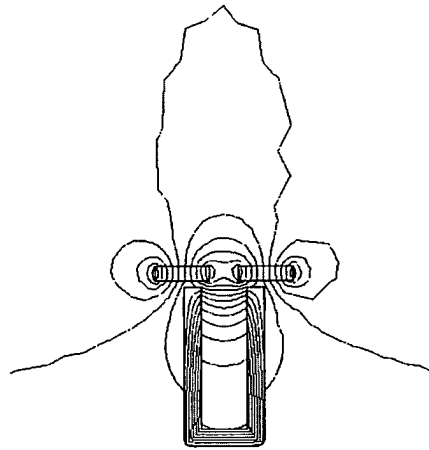


Fig. 3.b

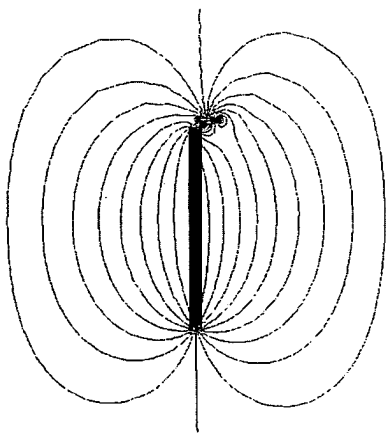


Fig. 3.c

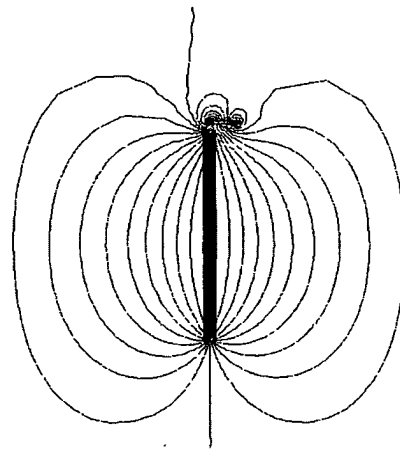


Fig. 3.d

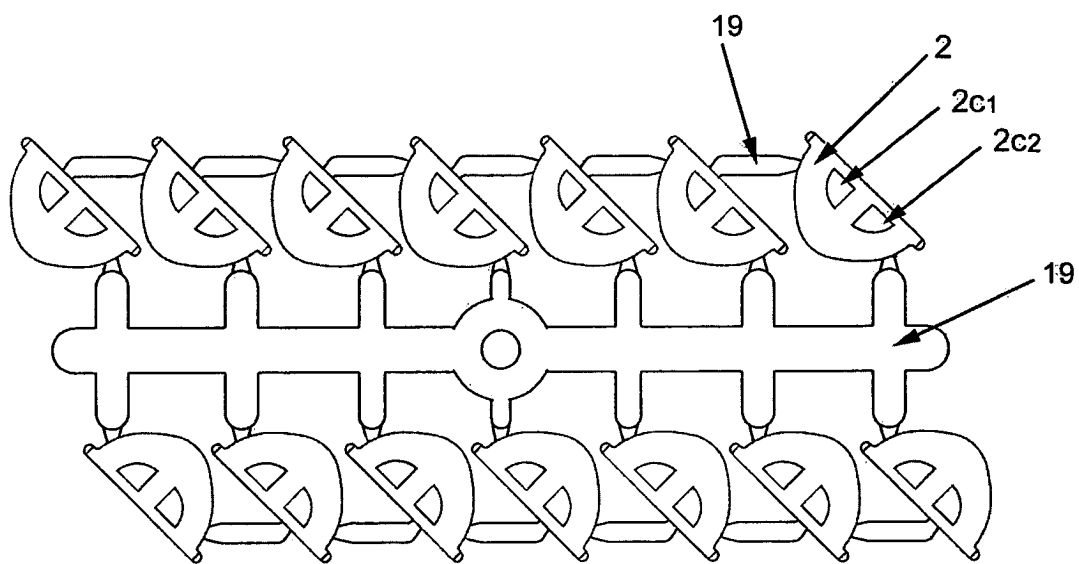


Fig. 4